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Sampling techniques for lakes and bogs

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INTRODUCTION

After a representative and suitable sampling site has been located, successful coring is necessary in order to ensure a sediment or peat sequence as complete and undisturbed as possible. Taking into consideration the long time usually required for later analytical work, it is clear that the time spent making a sampling is worth while; no laboratory or analytical techniques can compensate for poor sampling techniques. Disturbances and incompleteness of the sediment or peat core obtained, which may not be apparent in the field, may lead to serious misinterpretations.

A description will be given of some available and commonly used chamber samplers and piston samplers, and types suitable for sampling in different conditions will be recommended. Sampling from open sections, which may sometimes be possible particularly in peat deposits, will also be described.

CHAMBER SAMPLERS

The chamber samplers are filled from the side, and two types will be described — the Hiller sampler and the Russian sampler (Figure 8.1).

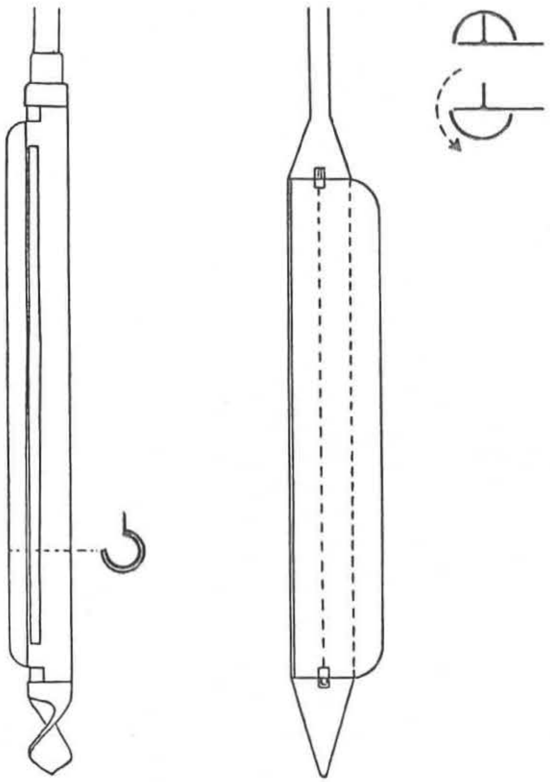

FIGURE 8.1. The Hiller sampler (left) and the Russian sampler (right)

Hiller sampler

This is operated by twisting the sampler and filling the chamber by cutting out a segment of sediment, which is scraped into the chamber. A gentle twist in the opposite direction closes the chamber.

This commonly used sampler is named after the Swedish peat engineer K. Hiller, but it should in fact derive its name from the Norwegian forester P. Chr. Asbjørnsen, who first described the prototype in 1868 (Fries and Hafsten, 1965). Its main feature is its robustness. It is usually capable of penetrating very

compact sediments and peats, and even rather deep deposits with a high minerogenic content. Therefore, the Hiller sampler is very useful for extensive or survey investigations in lakes and bogs. It should, however, only be used for these purposes as there is considerable risk of contamination.

Especially during penetration, the projecting flange of the rotating chamber is liable to catch resistant plant remains, which are transferred to a deeper position, causing contamination. Also the auger head disturbs the deposit as it penetrates, so that the actual stratigraphy may be disturbed. Another disadvantage of the Hiller sampler is that intact cores cannot be removed and samples must be taken in the field.

In order that the sampler remains rigid only a tiny slit is open to the chamber, which complicates the sampling procedure and makes for difficult cleaning.

Various modifications have been made. Thomas's (1964) modification allows the removal of intact cores by having a removable auger head. Although the Thomas modification is a great improvement, some of the serious disadvantages still remain.

The common length of the sampler is 0.5 m or 1 m, and the diameter is about 4 cm. The diameter should not be increased, since sampling by scraping presupposes instantaneous filling of the chamber, so as not to cause serious contamination.

Russian sampler

This sampler was originally described by Belekopytov and Beresnevich (1955) and later by Jowsey (1966). It is commonly used, and while the Hiller sampler scrapes the sediment into the chamber, the Russian sampler does not disturb the deposit. Penetration to the required depth allows the sampler to slide past the material which will be sampled. The chamber is rotated 180° and the edge of the semicylinder cuts around the material to be sampled, thus maintaining it in its original position. Sediment disturbances are thus minimized.

The Russian sampler has several advantages. The construction of the auger head and the fin flange prevent trapping fibrous remains. Sample collection in the field or removal of intact cores is easily undertaken as the semicylindrical core can be fully exposed on the fin. This exposure of the sample is also a considerable advantage because stratigraphy, humification, colour etc. can be described in detail, after the sediment surface has been cleaned.

The sampler is suitable for most types of homogeneous sediment and peat. However, in peat with larger wood remains or in compact minerogenic sediments, the auger head may easily be lodged and on rotating only the upper part of the semicylindric chamber turns, causing damage. Wood and small stones may also be caught between the fin and the cylinder edge, so causing the chamber to remain unlocked or to become damaged.

The common length of the sampler is 0.5 m or 1 m, and the diameter is about 5 cm. However, both can be modified if a larger sample quantity is wanted. Smith *et al.* (1968) have designed a useful modification — length 1.5 m and diameter 12 cm — for collection of an adequate quantity of material for close-interval radiocarbon dates.

Provided the sediment is sufficiently consolidated the Russian sampler can sometimes be used for studies on annual laminations and palaeomagnetism. In such studies continuous cores as long as possible are usually required. In homogeneous sediments the length of the sampler can be increased to at least 2 m, and due to its construction the orientation of the core required in palaeomagnetic studies can be obtained.

PISTON SAMPLERS

Principles of construction and operation

Piston samplers have been found to be the best for use in most types of lake sediments. Successful coring with a piston sampler requires (1) a knowledge of the major principles of sediment coring and sampler construction, and (2) a knowledge of the techniques of handling and operating a sampler. The former can be learned from available papers on coring and sampler construction. The latter can partly be learned from studying descriptions; however, the best knowledge about how to handle and operate samplers can be obtained only by practice and experience in fieldwork.

Thorough descriptions of the principles of sediment coring and sampler construction may be found in papers by, for example, Hvorslev (1949), Kjellman *et al.* (1950), Kullenberg (1947, 1955), Piggot (1941) and Emery and Dietz (1941). Some very good and detailed manuals of sediment coring by different types of piston samplers have been given by Wright *et al.* (1965) and Wright (1980). The present description of piston samplers will concentrate on summarizing some principles of sediment coring, and on surveying the different types of samplers available for coring in different conditions.

In Figure 8.2 a piston sampler is compared with an open drive sampler. The open sampler is simply a tube driven into the sediment. The hydrostatic pressure on the sediment core inside the sampling tube is the same as on the outside sediment. During coring the sliding resistance between the core and the inside tube wall will cause an increasing pressure on the sediment at the lower tube mouth. As the tube continues to be driven into the sediment, the progressively increasing pressure will lead to a downward deflection, stretching and thinning, and finally lateral displacement of the sediment. Gradually smaller and thinner increments of sediment will be added to the core, and when finally the inside sliding resistance exceeds the strength of the sediment

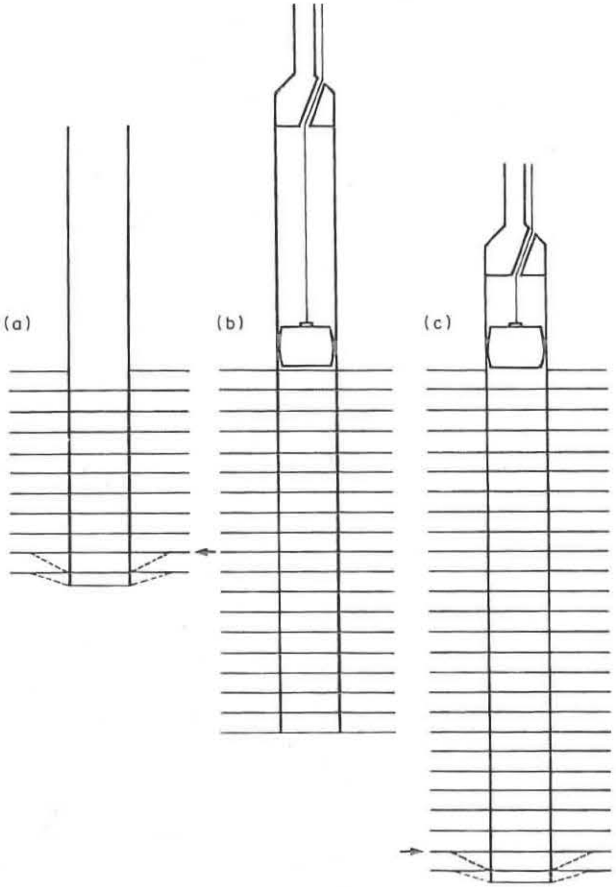

FIGURE 8.2. Simplified drawings showing coring with (a) an open drive sampler, and (b) and (c) a piston sampler. The arrow indicates beginning of downward deflection and thinning of sediment

no more sediment will enter the sampling tube. Further penetration by the tube will result in a cone of sediment formed in front of the tube mouth, and the sampler with the core will simply act as a solid pole, displacing all the sediment.

The 'safe length of sample' is, according to Hvorslev (1949), defined as the length of core that can be obtained before downward deflection of sediment begins. The 'limiting length of sample' is the length that can be obtained before a permanent cone is formed, when no sediment is added to the core. The 'total recovery ratio' can be calculated by dividing the length of core by the length of sampler penetration. It must be considered that below the 'safe length of

sample' any core obtained will be shortened, and will not represent a complete and correct sequence of sediment.

The important principle in the construction of the piston sampler is elimination of the hydrostatic pressure over the core inside the tube. The tight-fitting piston is kept immobilized immediately above the sediment, and the hydrostatic pressure on the sediment outside the sampling tube will oppose the inside sliding resistance and the creation of a vacuum between the sediment core and the piston. Not until the inside sliding resistance exceeds the hydrostatic pressure will no more sediment enter the sampling tube.

This means that piston samplers permit longer sediment cores to be obtained, and that the 'safe and limiting lengths' are related to the water depth and the hydrostatic pressure. If no vacuum has been created below the piston, the recovery and the representation of sediment must be complete. However, if a vacuum has been created, the penetration has exceeded the 'safe length of sample' and the lower part of the core will be shortened and disturbed.

In shallow and moderately deep lakes the positive (core length increasing) effect of the piston is mostly less than usually thought. Most of the light-weighted piston samplers, which are suitable for such lakes, have a sampling tube length of about 1 m. This length is determined partly by the convenience of handling and operation, but also by the possible 'safe length of sample' that can be obtained. The tube length can fairly easily be modified and increased; however, then it must always be checked that the safe length is not exceeded.

To obtain a complete sediment sequence, sampling of successive cores will usually be necessary. Such sampling should be made in alternate holes. To be sure that a complete sediment sequence is obtained, and to enable checking of possible disturbances of the uppermost and lowermost parts of the cores, the successive sampling should include 10–20 cm overlaps.

Besides the water depth and hydrostatic pressure, the 'safe length of sample' also depends on the diameter of the sampling tube, the properties of the sediment, and on the specific construction and operation of the sampler.

The length of core will increase by increasing the tube diameter; however, it must then be kept in mind that the ratio between the thickness of the tube wall and the diameter should always remain as low as possible. A thicker tube wall means that an increased quantity of sediment at the tube mouth has to be displaced inwards or outwards — in the former case increasing the inside sliding resistance. An increase of the tube diameter will also increase the risk of loss of core — or part of it — during core withdrawal. Most piston samplers are designed for a tube diameter of 5–6 cm, but in most sediments this can, if required, be increased to 10 cm without there being a great risk of core loss.

With regard to the character of sediment, it is evident that several properties can fairly significantly affect the length of core — for example, the organic and minerogenic content, the water content and consolidation — influencing the cohesion and strength of the sediment and the inside sliding resistance. The effects of different properties are not always precisely known. However, even if they were, this knowledge would be difficult to apply in each separate coring. After some corings in sediments of varying character the effects of different properties will be empirically learned.

The effects of various methods for driving the sampling tube into the sediment have been thoroughly discussed by Hvorslev (1949). It is recommended that, whenever possible, the driving is performed in one fairly fast and uninterrupted pushing. This to prevent the development and building-up of inertial adhesion and friction, increasing the inside sliding resistance. To reduce the risk of loss of the core — or part of it — a pause should be made before the withdrawal and lifting of the sampler. In compact sediments where the sampler has to be operated by a chain-hoist or by hammering, it should be attempted to make the driving as steady and uninterrupted as possible.

For various specific details of sampler construction the reader is referred to the descriptions in Hvorslev (1949) and Kjellman *et al.* (1950) (e.g. shape of cutting edge of tube, inside and outside clearances of the tube mouth). The effects of these details on light-weight and hand-operated piston samplers will be fairly insignificant.

As described, piston samplers will, particularly in deep water, permit the retrieval of long, continuous and undisturbed cores. However, by increasing the tube length and penetration, the inside sliding resistance will sooner or later be a limiting factor. A piston sampler with metal foils constructed by Kjellman *et al.* (1950) is at present the only available sampler in which the sliding resistance is completely eliminated. The core is surrounded by a number of foils fixed to the piston, and accordingly does not slide against the inner tube wall. Unfortunately, the foil sampler is expensive and requires heavy and complicated equipment for operation, which means that its use can usually only be considered in special coring work. Owing to its construction the sampler can be used only on land or in fairly shallow water.

Livingstone (1967) has described another use of foils for reducing the sliding resistance, which is apparently effective provided that strong enough foils can be obtained.

Many drawings of different types of piston samplers may give the impression that constructing a sampler is difficult. However, all that is required for a useful light-weight and hand-operated sampler is a sampling tube, a piston and some driving rods. Knowing the principles of operation, it should be possible for most people to design and construct their own sampler, which on the evidence of the large number of modifications would seem to be the case.

Samplers for shallow lakes

The choice of sampler type is largely determined by the water depth of the lake.

In shallow lakes, samplers operated by rods can be used. Such samplers are recommended, whenever possible, since they mostly allow a thorough and continuous control of the coring; depth of sampler penetration and core recovery can easily be determined and checked. A light-weight rod-operated piston sampler has been described by Livingstone (1955). Modifications and improvements have been presented by among others Vallentyne (1955), Walker (1964), Cushing and Wright (1965), Wright (1967) and Merkt and Streif (1970). A fairly light-weight rod-operated sampler has also been described by Wieckowski (1970). All these samplers are designed for taking approximately 1 m cores, but this length can be modified. The sampler described by Wright is to be recommended, because it is both simple in operation and strong in construction, which permits coring even in very compact sediments. A further modification for taking longer cores (3.5 m and 7.5 m) has also been described (Wright, 1980).

The water depth in which rod-operated piston samplers can be used varies somewhat depending on the character of the sediment. When coring in compact sediments rods may bend even in fairly shallow water. In such cases — and always in deeper water — casing tubes should be used to stabilize the rods, so preventing them from bending when the sampler is driven into the sediment.

Since rod-operated samplers are to be preferred, the use of casing is also generally recommended for water depths down to 20 m. The use of casing is possible in deeper water, but then additional equipment and other means of assistance are required, which are not usually available in general coring exercises.

Most rod-operated piston samplers can also be used for peat coring in bogs, provided that the peat is below the water table and completely saturated. The samplers work best in highly to moderately humified peat, but it is important to use tubes as thin-walled as possible with sharp cutting edges. Coring in slightly humified and fibrous peat, and in peat rich in large wood pieces, is usually problematic or impossible.

When sampling in drained peat, not completely water-saturated, the core will mostly become significantly compacted. Smith *et al.* (1967) constructed an open-drive sampler in which the tube had a longitudinal slit to prevent compaction. Another sampler that may sometimes be useful in peat coring was described by Couteaux (1962). The sampler is made of two half-tubes, and in construction it is something between a side-cutting and an open-drive sampler. In cases when peat coring by use of a piston sampler is impossible or problematic, a large-capacity Russian sampler may also be recommended as a useful alternative.

Samplers for deep lakes

In very deep lakes certain types of piston sampler have to be chosen which are lowered by cables, and in which a force other than that of driven rods is used for pushing the sampling tube into the sediment. In the Kullenberg piston sampler (Kullenberg, 1947, 1955) the driving force is obtained by a combination of loading and free-fall. The exact water depth need not be known, since the piston is automatically locked and immobilized when the sampler is some distance above the sediment surface. The original Kullenberg sampler was constructed for deep-sea coring, and the equipment required is both heavy and complicated. However, light-weight and more easily operated modified designs can be constructed, which are suitable for coring in deep lakes (Wright *et al.*, 1965).

In the deep-water sampler constructed by Mackereth (1958; Smith, 1959) compressed air provides the driving force. The compressed air is used both for fixing an anchoring chamber and for driving the sampling tube into the sediment. The equipment is fairly complicated, but the sampler can be operated from a small boat.

In difficult terrain, where it may be impossible to transport any heavy equipment, some simple constructions of light-weight deep-water samplers can be recommended. These samplers, described by Huttunen and Meriläinen (1975) and Digerfeldt (1978), are lowered by cables and then smoothly hammered down into the sediment by a moveable load of moderate weight (in soft sediments a few kilograms may be enough).

The higher hydrostatic pressure in deep lakes means that longer continuous cores can be obtained. However, whenever possible the recovery must be checked, and the user should be aware that the lower part of the core may be shortened and incomplete. In using the Mackereth sampler or a modified Kullenberg sampler the length of the sampling tube can be varied, but the driving has to begin at the sediment surface and the operation completed if possible in one attempt. An advantage with the Digerfeldt sampler is that sampling of successive sediment sequences is possible, since the piston, provided that the sediment is not too compact, can be locked at the tube mouth by a break-pin. This is important when the hydrostatic pressure is not high enough to permit a continuous sampling of the whole sediment sequence in one drive. Another advantage is that the sampler can be withdrawn and lifted by a ball-clamp, which is lowered and clamped to a short rod attached to the sampler head. A problem in deep-water coring is that usually the sediment thickness cannot be determined in advance of sampling, so that the correct length of tube has to be guessed. If the whole length of tube is not driven into the sediment, and the piston is accordingly not displaced and locked at the sampler head, the piston cable on the Digerfeldt sampler need not be used for withdrawal and lifting. This means that possible disturbance of the upper part of the core by suction can be avoided.

Surface sediment sampling

To obtain undisturbed cores of the frequently loose and unconsolidated surface sediment (the upper 1 m approximately) special samplers are sometimes

required, and several different types have been described. In cases where fine structural sediment features have to be recorded — e.g. annual laminations — and a large quantity of sediment is not required, the use of frozen-core samplers is recommended. The different types available are described in Chapter 17.

Other surface sediment samplers can be divided into two major types — open samplers (i.e. without pistons) and samplers with stationary pistons. The former type can be used when a core of only the uppermost 20–30 cm is needed. Most of these samplers are lowered and operated by rope, and are often loaded to ensure sufficient penetration. The samplers are therefore easily handled, and can be used in both shallow and deep water. To prevent the sediment core from slipping out during withdrawal and lifting, the open upper end of the sampling tube must be closed by a stopper or similar efficient closing mechanism. The 'safe length of sample' will vary depending on the character of sediment, but heavy loading to obtain a longer core should generally be avoided. Owing to the slight consolidation of the surface sediment, the sliding resistance inside the tube will, sooner than is usually thought, cause a downward deflection and lateral displacement of the sediment, resulting in incomplete and disturbed samples. In cases where it is intended that the surface sediment core is to be used, for example, for thorough dating and reconstruction of changes in accumulation rate and different influx calculations, such problems may lead to serious misinterpretations.

Håkansson and Jansson (1983) have discussed various aspects of surface sediment sampling and described some available types of samplers. The well-known Jenkin sampler (Mortimer, 1942) and Kajak sampler (Kajak, 1966) belong to this category of open samplers, but the former seems to be unnecessarily complicated.

Wright (1980) recommends a very simple and efficient surface sediment sampler constructed by Hongve (1972). Probably even simpler, but equally efficient, is the sampler designed by Benoni and Enell (Figure 8.3).

For sediment X-ray work and special studies of structural features, Axelsson and Håkansson (1972) have designed a surface sediment sampler with rectangular sides.

Most of the rod-operated piston samplers can also be used for surface sediment sampling. However, some special modifications have been constructed (Rowley and Dahl, 1956; Brown, 1956; Davis and Doyle, 1969). The problems most likely to be met are connected with high water contents and slight consolidation. In order to avoid disturbances and lateral displacement of the sediment, the driving of the sampling tube should be made as smoothly as possible. Subsampling of the core has to be made with the tube in the vertical position and usually by upwards extrusion of the sediment. Good techniques for extrusion are described by Wright *et al.* (1965) and Håkansson and Jansson (1983).

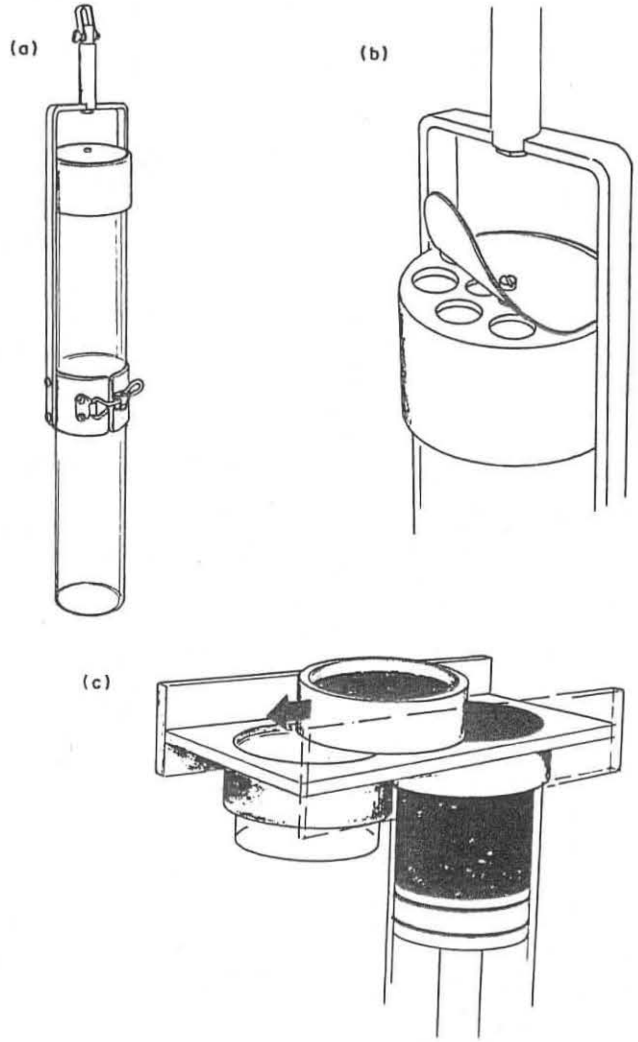

FIGURE 8.3. The surface sediment sampler designed by S. Benoni and M. Enell (Institute of Limnology, Lund, Sweden). (a) The sampling tube is made of transparent plastic, 50 cm in length and 7.5 cm in diameter, and it is easily exchangeable. (b) Detail of valve which is put on top of sampling tube. The valve, which is made of 1–2 mm rubber sheet, prevents the sediment core from slipping out as the sampler is withdrawn. (c) Detail of sectioning device, which can be put on top of sampling tube. Subsampling is made by upwards extrusion of sediment core

Cable-operated deep-water samplers, as described above, which allow the tube to be smoothly driven, can also be used for reliable surface sediment sampling. Mackereth (1969) has designed a modification of the compressed-air sampler for undisturbed sampling of the upper 1 m of the surface sediment. When a particularly large quantity of surface sediment is required, Digerfeldt and Lettevall (1969) have described a square-formed (10 × 10 cm) piston sampler. The core is prevented from slipping out by automatically released closing plates at the sampler mouth. Undisturbed subsampling is made possible by inserting partition plates, after which the sampler can be placed horizontally and one side opened. This sampler can be operated by either rods or cable (Digerfeldt, 1978), and accordingly can be used in both shallow and deep water.

SAMPLING FROM OPEN SECTIONS

In many bogs, old peat exposures, drainage ditches or other features may represent valuable sites for palaeoecological studies, since the stratigraphy can be inspected in detail. What may look homogeneous in a core may sometimes be divided into two or more distinct layers in an open section. Similarly, former irregular sediment accumulation features or artificial disturbances may be detected in open sections, whereas they may remain undiscovered in cores. In addition, the risk of contamination is reduced and the amount of sediment obtainable at each level is unlimited when sampling from open sections. Because of these advantages, sampling from open sections is recommended instead of coring, whenever possible.

Samples are collected directly in the field, if conditions are convenient, or exposures can be examined and complete monoliths removed to the laboratory before extraction of samples takes place. Especially if the content of resistant material (e.g. wood remains) is considerable, or if the peat is loose and only weakly decomposed, it is desirable to dig monoliths and freeze them before further treatment (see Chapter 6). Sediments with a high content of minerogenic matter are best collected directly from the section, as they are fragile.

Open sections may be excavated even at places with a high water table, but no general recommendation can be given as local conditions may vary considerably in the same mire type. Practical experience shows that monoliths can be extracted from undisturbed ombrotrophic mires to a depth of approximately 2 m if the stratum is moderately or strongly humified, whereas digging is almost impossible in weakly humified peat. Investigation holes may also be difficult to excavate in artificially drained peat deposits, because waterlogged cracks are common and, by perforation, water quickly pours out and impedes any water control.

Therefore automatic pumping is generally needed when carrying out

successful investigations in newly excavated pits. It should be stressed that buttress constructions are required in deeper holes to prevent collapsing of the peat walls.

When collecting an entire monolith it is important to be aware of compaction after the column has been released from the section and is still in a vertical position. The total length should therefore be measured and matchsticks inserted at intervals (e.g. 10 cm) before the column is released. Compaction is insignificant in partly drained deposits where shrinkage of the peat has already progressed and in deeper deposits which have already been exposed to autocompaction. On the other hand, shrinkage may be considerable in the upper part of weakly decomposed peat where there is a high water content. After removing the monolith it is easy to compensate for an actual compaction.

The size of the peat column may vary, but for most investigations a 10 × 10 × 150 (max.) cm column will be ideal. In longer sections, alternating columns are sampled and the overlap should be at least 10 cm. Metal boxes with a few perforations in the back are useful for sampling.

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